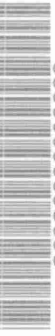


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REPORT ON WATER QUALITY IN MOIRA LAKE

1972



Ontario

Ministry
of the
Environment

The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

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REPORT ON WATER QUALITY

IN

MOIRA LAKE

1972

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PREFACE

The Province of Ontario contains many thousands of beautiful small inland lakes which are most attractive for recreational use. Lakes close to urban areas and accessible by road often receive heavy use in terms of cottage development, camp sites, trailer parks and picnic areas.

A heavy influx of people may subject a lake and its surrounding environment to great stress. In many cases, developments are carried out on attractive lakes only to find that when this is complete the lake qualities which were initially so appealing have been damaged. The appearance of the shoreline can be marred by construction, fishing ruined by over harvesting or the growth and decay of excessive amounts of algae and weeds. Motor boats introduce noise and petroleum pollution. Inadequate disposal of human wastes can place a great stress on the lake environment.

The accepted custom of having "a place at the lake" continues to apply pressure for more development, giving rise to an ever greater expansion of problems.

The Ontario Ministry of the Environment is attempting to bring some of these stress factors under control with a variety of programs. The cottage pollution control program was initiated in 1967 and was expanded in 1970 in order to solve the cottage waste disposal problem in recreational lakes. There are three on-going studies carried by the Ministry:

- 1) evaluation of existing waste disposal systems and enforcement of repairs to those found to be unsatisfactory.

- 2) research to improve the knowledge of septic tank operation and effects in shallow soil areas and evaluation of alternative methods of private waste disposal.
- 3) evaluation of present water quality in a number of recreational lakes. A totally undeveloped lake near Huntsville was studied in 1972, in order to obtain more information about natural water quality conditions within a Precambrian Lake, which would assist in defining any unnatural conditions encountered in the developed lakes surveyed.

This report on Moira Lake is one of a series dealing with the water quality aspects of the recreational lakes studied in 1972. As well as defining the present status of water quality in the lakes, the data are meant to provide an historical reference for comparison of conditions at any future time.

SUMMARY

Surveys were carried out on Moira Lake in 1972 to evaluate the present status of the water quality with respect to bacteria, algae and aquatic plant growth. Plant nutrient and dissolved oxygen concentrations in the surface and bottom waters were determined.

Moira Lake is in the County of Hastings and lies within two distinct bedrock regions. Its north-east shore lies within the Precambrian Shield and is characterized by rocky outcroppings and shallow overburden covering the bedrock. The remainder of the lake is in the Trenton Black River geological region which is characterized by flat topography with poor local drainage. This area has several feet of overburden covering the limestone bedrock.

The major body of Moira Lake was found to be within the Ministry of the Environment Bacteriological Criteria for total body contact recreational use (MOE 1972). The Moira River inflow was influenced by a minor bacteriological contamination input but still within the MOE criteria, however, the area within the influence of Deer Creek exceeded this criteria and was considered a health hazard.

Deer Creek was also the source of the highest concentration of phosphorus and other nutrients entering Moira Lake. Following termination of the direct discharge of municipal wastes from Madoc in the summer of 1972 and even during the first seasonal discharge of treated wastes from the new municipal lagoon in the spring of 1973, an improvement in the chemical and

bacterial quality of Deer Creek was shown.

This should eventually result in improved water quality in Moira Lake, particularly when phosphorus removal facilities are added in late 1973 to Madoc's sewage works. Improvement will be gradual since the lake is extremely enriched and supports both algal and plant communities, each of which thrives to an objectionable degree.

While arsenic is present in Moira Lake, intensive water quality monitoring within the Moira River basin by both the Ministry of Health and the Ministry of the Environment over the past several years has revealed a steady improvement with arsenic concentrations now approaching the Ministry's objectives.

PURPOSE OF THE SURVEYS

The surveys were designed, and tests selected, in order to evaluate the present conditions in the lakes with respect to:

- concentration of bacteria
- plant nutrients and algae
- water quality with depth
- density and species of aquatic plants
- inventory of shoreline development

As a result of human activity in the recreational lake environment, some wastes may reach the lake itself and this can lead to either or both of two major types of water quality impairment, microbial contamination and excessive growths of algae and aquatic plants. The two problems can result from a common or different source of pollution, but the consequences of each are quite different.

Microbial contamination by raw or inadequately treated sewage does not significantly change the appearance of the water but poses an immediate public health hazard if the water is used for drinking or swimming. This type of pollution can be remedied by preventing wastes from reaching the lake and water quality will return to satisfactory conditions since most disease causing bacteria do not persist in the lake.

Nutrient enrichment, or eutrophication, results from the addition of plant fertilizers which occur naturally and are also present in virtually all forms of raw or treated human wastes. High concentrations of these fertilizers (plant nutrients), mainly nitrogen and phosphorus, support extensive

growths of rooted aquatic plants and of microscopic free-floating plants called algae. Eutrophication greatly affects the lake appearance but generally does not pose a health hazard. Problems due to nutrient enrichment are generally long lasting and may become irreversible.

Changes in water temperature, dissolved oxygen and quality with depth are very important characteristics of a lake and were examined in the surveys.

The growth of weeds along the shore was noted during the surveys. Aquatic weed beds provide shelter and food for many kinds of fish. Too much growth is undesirable since it can upset the oxygen balance in the lake and can interfere with recreational uses of the lake.

DESIGN OF THE SURVEYS

Timing

Five day bacteriological, chemical and biological surveys were carried out from June 18-23 and August 21-25, on Moira Lake a chemical and biological survey was repeated on September 11 to 13, 1972.

A proper estimation of the bacterial population requires several measurements over a period of time, which can then be averaged as a geometric mean. Measurements over 5 consecutive days at each station are regarded as the minimum number which will give reliable bacterial data.

Chemical samples were collected on the first and last days of the surveys at inlet and outlet stations and on the first, third and fifth days at the mid lake stations. Chlorophyll samples were collected each day at the inlet and mid lake stations.

Selection of Sample Locations

Thirty-six bacteriological sample sites were established over the whole lake. Chemical samples were collected at 2 inlet stations, 1 outlet station and at 3 mid-lake stations. In addition to these surface samples, chemical and bacteriological samples were taken from the bottom water at the mid-lake stations. Aquatic plant samples were collected in areas representative of sparse, medium and dense growth.

Field Tests

The temperature and dissolved oxygen values were measured at the deep water stations with an electronic probe lowered into the lake and water clarity was measured with a Secchi disc (Figure 1). The pH and conductivity of the samples were measured in the field.

Bacteriological Tests

Three groups of bacteria were determined on each sample: total coliforms, fecal coliforms, fecal streptococci. These organisms are used as "indicators" of fecal contamination. Many diseases common to man can be transmitted by feces, consequently, the probability of occurrence of these diseases is usually highest in areas where the water is contaminated. The total coliforms, fecal coliforms and fecal streptococci organisms are all indigenous to man and other warm blooded animals and are found in the colon and feces in tremendous numbers. Hence, these indicator organisms in the water denote the presence of fecal contamination and hence the risk of disease causing organisms.

Standard plate count (SPC) determinations were made on some mid-lake stations in order to determine densities of some natural water bacteria.

The "Secchi Disc Reading" is obtained by averaging the depth at which a 23cm (9") dia. black and white plate, lowered into the lake just disappears from view and the depth where it reappears as it is pulled up.

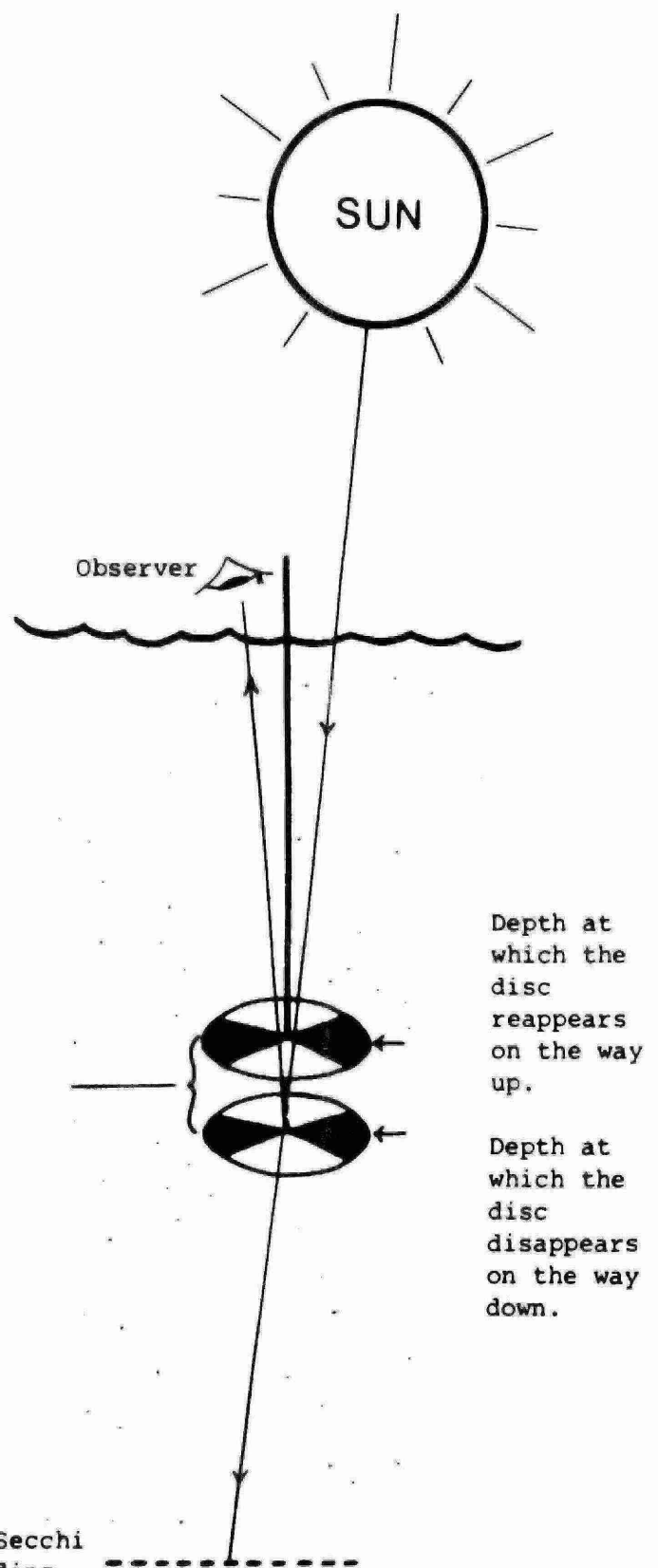
Most of the free-floating algae are suspended in the illuminated region between the lake surface and 2 times the Secchi disc reading.

Secchi Disc Reading

Clear, algae-free lake:
Secchi disc readings tend to be greater than 3m (9 feet).

Turbid or algae-rich lake:
Secchi disc readings tend to be less than 3m (9 feet).

2 times Secchi disc reading



The SPC media will only support the growth of those organisms that don't require special nutrients, oxygen requirements and/or incubation temperatures. The SPC is used as a measure of general bacterial activity.

Chemical Tests

Hardness, alkalinity, chloride, iron and conductivity were measured in order to define the mineral composition of the water. The types of plants and animals which thrive, effects of toxic materials and suitability of the lake for various management techniques depend on the mineral content.

Total and soluble phosphorus were measured in the inlet and bottom water samples while total phosphorus only was measured in the mid-lake and outlet surface samples. Soluble phosphorus concentrations are used mainly to substantiate various interpretations of the total phosphorus concentrations. Arsenic was determined to assess a possible interference with the phosphorus analyses.

The total Kjeldahl nitrogen is essentially the amount of nitrogen contained in organic material. It was measured in all of the chemical samples. The soluble forms of nitrogen, ammonia, nitrite and nitrate were measured in the inlet and bottom water samples. They are particularly important in bottom waters since nitrogen is regenerated from decaying organic matter in these forms.

Chlorophyll a concentrations are an indication of the amount of algae in the water. The live algae are confined mainly to the lighted surface waters which extend down to a depth of about twice the Secchi disc reading. The chlorophyll samples were collected by raising the sample bottle through the depth of the illuminated zone as it filled. The sample was then repre-

sentative of the average number of algae through the depth of the surface waters.

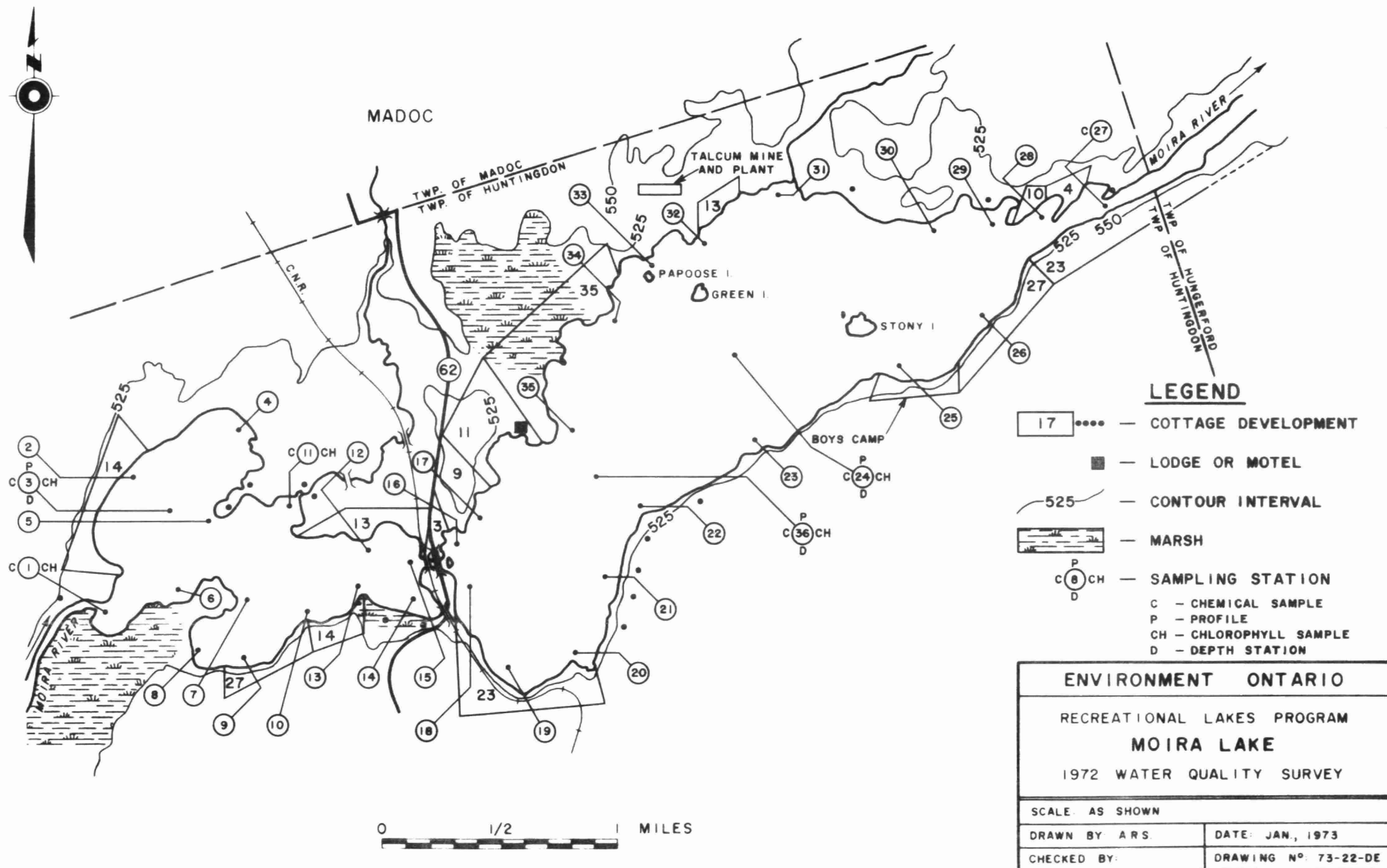
DESCRIPTION OF THE MOIRA LAKE AREA

Soil and Lake Characteristics

Moir Lake is located in the Township of Huntingdon in the County of Hastings and is approximately 1.6 kilometers (1 mile) south of the Village of Madoc.

The area surrounding Moira Lake generally has a rolling to a moderately hilly terrain. About 60 percent of the shoreline is rocky and the soil is mostly of the sandy loam variety. Generally the area is moderately to densely forested with the majority of the trees being deciduous. The north-east shore of Moira Lake lies within the Precambrian Shield while the rest of the lake lies within the Trenton Black River geological region. The steeply sloping southern shore of the lake and most of the north shore of the inflowing Moira River consists of the Dummer shallow loam series (Figure 2). The soil is well-drained and is usually 60 to 90 centimeters (24 to 36 inches) deep. Much of the area surrounding the south shore of the outflowing Moira River also belongs to this series. The north-eastern shore of the lake, which ascends from the lake with a gradual slope, is composed of from 50 to 90 percent rock and is known as the Rockland series. It contains small deposits of Muck and sandy loam in the crevices of the rock. Most of the northern shore and the shores of Deer Creek belong to the Bondhead Sandy loam series. This soil type usually is well-drained, moderately to gradually

FIGURE 2 - COTTAGE DEVELOPMENT AND SAMPLING STATIONS OF MOIRA LAKE



sloping and 30 to 60 centimeters (12 to 24 inches) deep. The remaining sections of the north shore around the mouth of the Moira River and the south-west shore of the west basin belongs to the Muck series. The Muck series is usually flat land composed of 38 centimeters (15 inches) or more of partially decomposed organic material with poor drainage, overlying a bed of mineral soils. The western shore of Moira Lake consists of a thin mantle of glacial till over limestone bedrock or moderately sloping land. The loam material is generally derived from limestone and is thus slightly alkaline in nature. A small section by the inflowing Moira River is Farmington loam. This section has less than 30 centimeters (12 inches) of glacial till overlying bedrock.

Moira Lake with its elongated shape can be considered as an expansion of the Moira River which constitutes its main inlet and outlet. The lake is divided into two basins separated by a natural narrows directly south of the Village of Madoc. The lake shoreline is 24 kilometers (15 miles) in length excluding 0.8 kilometers (0.5 miles) of island shoreline and has a surface area of 8.3 square kilometers (3.2 square miles). The mean depth of the combined sections of the lake is approximately 5 meters (15 feet) while the maximum depth is approximately 11 meters (36 feet).

Moira Lake lies in the Upper Moira River watershed, which is located in the north-west section of the Moira River Drainage Basin. The immediate watershed of the lake covers an area of 590 square kilometers (227 square miles). There are four inlets draining into Moira Lake. Two of these can be considered as insignificant, as they drain ponds and a large number of swamp areas and as such are extremely slow moving. The third inlet is

Deer Creek which flows through the Village of Madoc and enters a swampy area at the north shore of the west basin of the lake. North of the Village of Madoc, Deer Creek is known as Madoc Creek. This creek drains one small lake called Hazzard Lake.

The major inlet is the Moira River which originates about 18 miles north of Moira Lake and drains a large number of swamp areas and a few small lakes such as Wolfe, Eldorado and Jarvis. As such Moira Lake is the first basin for the headwaters of the Moria River. As well as being the major inlet, the Moira River is the lake's only outlet. It flows out of the lake's east end, through Stoco Lake and eventually flows through the City of Belleville into the Bay of Quinte.

Water Usage

The majority of the cottagers and the Village of Madoc use wells as their source of domestic water supply. The Village of Madoc is served by a municipal water works system which obtains its supply of water from a 160 foot deep well. Chlorination is the only treatment provided at this water works and it is being used for disinfection.

Due to the excessive weed and algal growths, recreational usage has been limited to boating and fishing. According to information available from the Ministry of Natural Resources, the lake offers an excellent sport fishery of walleye, maskinonge, northern pike, smallmouth and largemouth bass. The lake has received continuous plantings of maskinonge since 1953. Natural spawning beds are excellent for all warm water species.

The Village of Madoc had an inefficient primary sewaage treatment plant. In 1972 the village had a waste stabilization system constructed which will

improve the quality of the effluent being discharged and provide a greater measure of protection to the water quality of Deer Creek. The system has a seasonal discharge in the spring and fall. Both cells are now in full operation and nutrient removal treatment will be incorporated by the end of 1973.

The area residents are provided with two municipal refuse disposal sites located within two miles of the lake. According to information provided by our Waste Management Branch, the site located on Lot 12, Concession XIII, Huntingdon Township, is to be closed and the site located on Lot 2, Concession IX is to be upgraded. There is also a private site located on Lot 17, Concession XIII, Township of Huntingdon.

Shoreline Development

The shoreline of Moira Lake is well developed with the exception of the north-west and south-west shore of the west basin. There are approximately 270 cottages, 10 resorts and a summer camp on the lake. There are no urban communities on the lake but the Village of Madoc is located two miles north of the lake (Figure 1).

RESULTS AND DISCUSSION

Bacteriology

The quantities of bacteriological data necessitated statistical methods to summarize the results into a concise presentation without the inconsistency associated with manual interpretation. The methods used are based on the analysis of variance and Barlett's test of homogeneity by which stations on a lake can be grouped into areas with the same bacterial level. Areas or stations with only slight differences in bacterial concentration can

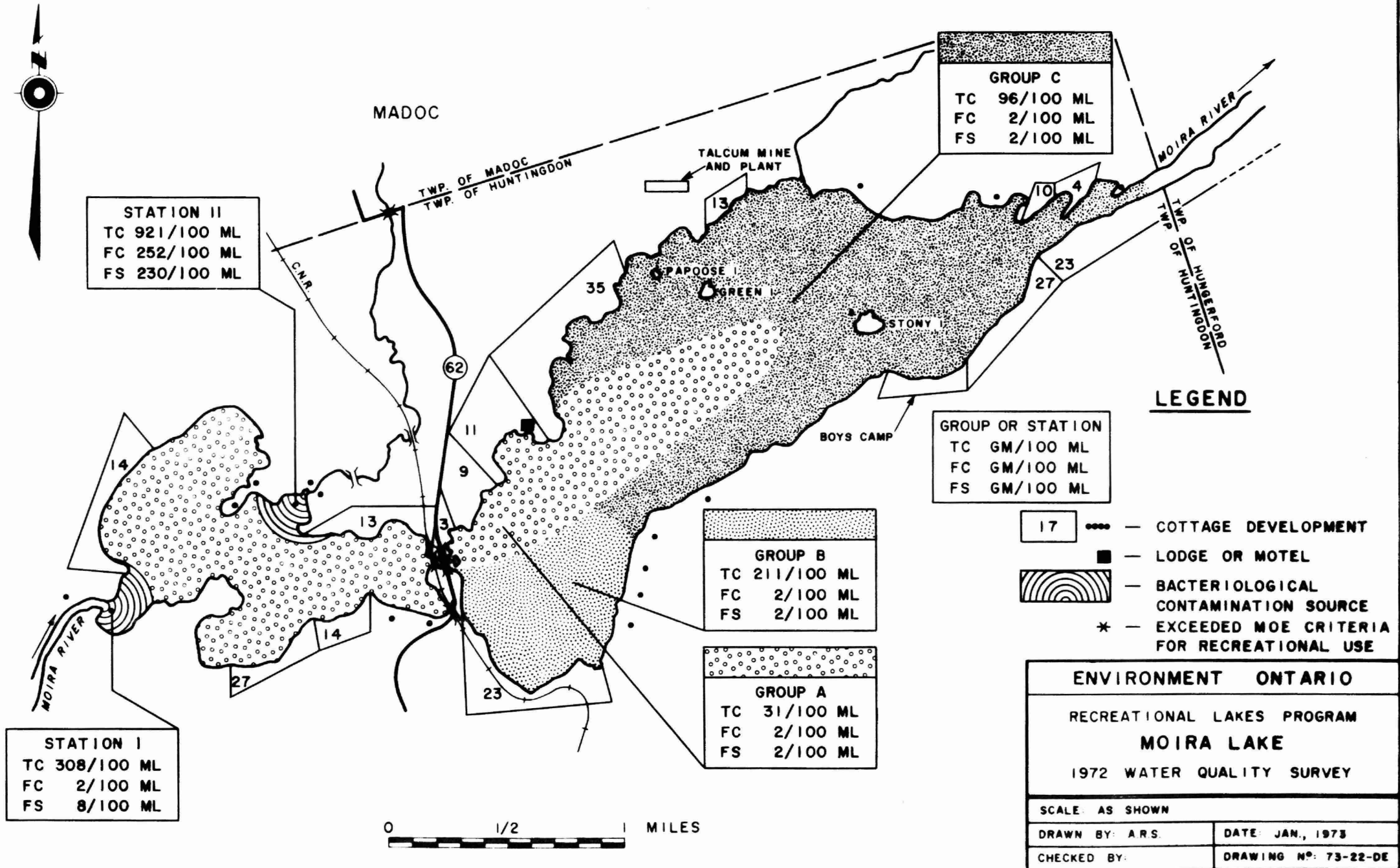
be isolated. It was found on previous work that areas, or stations, with significantly higher bacterial numbers generally indicated a pollution input. Details of statistical methods and data are available on request.

During the two surveys conducted Moira Lake was found to be acceptable bacteriologically, and within the Ministry of the Environment (MOE 1972) Criteria which states: "Where ingestion is probable recreational waters can be considered impaired when the coliform (TC), fecal coliform (FC), and/or enterococcus (FS) geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively....". (1)

During the spring survey the western basin (Group A), generally had a low total coliform (TC) geometric mean (GM) of 31 TC/100 ml (Figure 3). Groups B and C found in the eastern basin had higher total coliform counts of 211 TC/100 ml and 96 TC/100 ml respectively. Fecal coliform (FC) and fecal streptococcus (FS) populations were homogeneous throughout the lake with the exception of the two inlets. The inflow of the Moira River (Station 1) had geometric means of 308 TC/100 ml, 2 FC/100 ml and 8 FS/100 ml. The discharge of Deer Creek (Station 11) had substantially higher counts with means of 921 TC/100 ml, 252 FC/100 ml and 230 FS/100 ml. This discharge was a definite pollution source to the lake and greatly exceeded the MOE Criteria for fecal coliform and fecal streptococcus while TC concentrations approached the recreational safety limit. These higher counts in Moira Lake, within the influence of Deer Creek, were probably due to the discharge of sewage from the Municipality of Madoc.

During the summer survey, Moira Lake had lower overall counts than were encountered in the spring survey. The major portion of the lake

FIGURE 3 - DISTRIBUTION OF BACTERIA IN JUNE



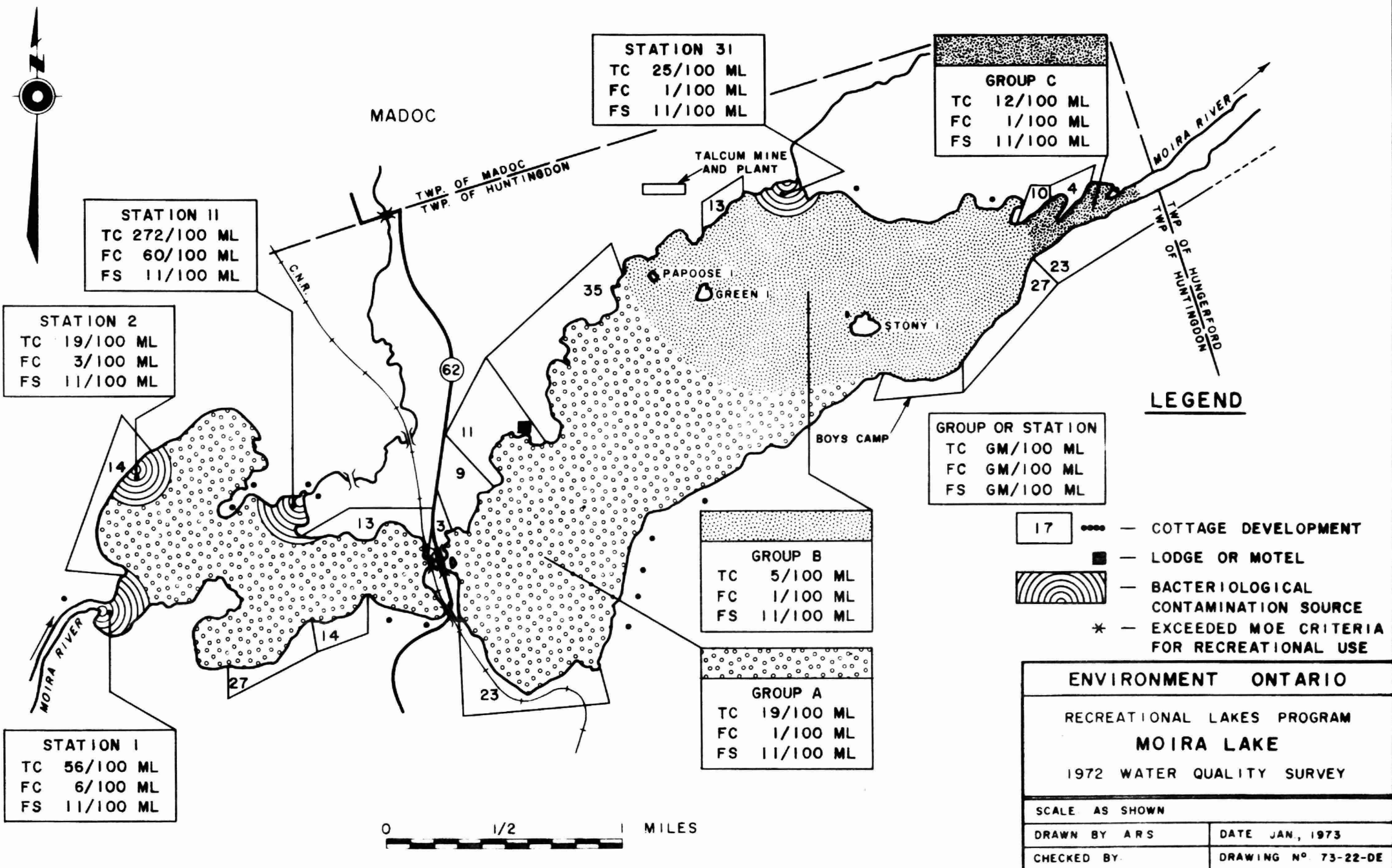
(Group A) had a mean total coliform count of 19 TC/100 ml (Figure 4). A large part of the north-eastern basin at the outflow of the lake (Group B), had a geometric mean of 5 TC/100 ml. FC and GS throughout the lake were insignificant with means of 1/100 ml.

The isolated Stations 1, 2, and 3 displayed higher means and indicated areas of minor bacterial input in Moira Lake. The inflow of the Moira River (Station 1) had 56 TC/100 ml, 6 FC/100 ml, and 11 FS/100 ml. The area in front of Bailey's Cottages (Station 2) on the extreme western edge of Moira Lake had 19 TC/100 ml, 3 FC/100 ml, and 11 FS/100 ml. A stream in the eastern basin (Station 31) displayed means of 25 TC, 1 FC, and 11 FS/100 ml. The outflow (Station 11) of Deer Creek, once again had the highest means of 272 TC, 60 FC and 11 FS/100 ml. Although these bacterial levels are very high they are below the Ministry of the Environment Recreational use Criteria and considerable lower than the bacterial levels in June. This improvement was probably a result of the completion of the lagoon system in July 1972. Additional data obtained from the MOE River Basin Monitoring indicate that the bacteriological water quality of Deer Creek has continued to improve later in 1972 and in 1973.

(1) Guidelines and Criteria for Water Quality Management in Ontario.

MOE 1972.

FIGURE 4 - DISTRIBUTION OF BACTERIA IN AUGUST



Chemistry

Moir Lake is divided into two basins, with some restriction of flow between them. The smaller western basin is fed 90% by the Moira River (Station 1) and 10% by Deer Creek (Station 11) (Figure 1). The larger eastern basin is fed from the western basin and empties into the Moira River at Station 27. Throughout the survey, the east basin had lower concentrations of most chemical compounds.

Hardness in the eastern basin was 130 mg/l in the June survey, increasing to 140 in the August and September surveys. Hardness in the western basin at Station 3 was 150 in June, increasing to 166 in the August and September surveys. This was almost the same as for the Moira River measured at Station 1. Hardness at the Deer Creek inlet was extremely variable with a range of 170 to 250 mg/l, with most values over 220 mg/l.

Alkalinity and conductivity values changed in proportion to the changes in hardness at all stations. Alkalinities ranged from 109 to 223 mg/l and conductivities from 250 to 460 micromhos/cm³.

Chloride concentrations in the eastern basin increased from 5-6 mg/l to 7-8 mg/l through the survey period. Station 11 chloride ranged from 9 to 12 mg/l throughout the survey, indicative of the sewage content of the stream at that time. Chloride in the western basin was intermediate between the eastern basin and Station 11 throughout the survey.

Arsenic concentrations were determined during the August and September surveys. At Station 11 the August survey showed arsenic values of 0.03 to 0.04 mg/l which is within the permissible maximum for drinking water

supplies of 0.05 mg/l. The other five chemistry stations (Figure 2) showed arsenic levels well above 0.05 mg/l with most over 0.10 mg/l. None exceeded 0.16 mg/l.

The September survey showed arsenic concentrations between 0.06 and 0.09 mg/l at all stations. Further sampling of Deer Creek throughout the fall of 1972 and winter of 1972, 1973 by the Water Quality Surveys Branch of the MOE showed that arsenic remained below 0.02 mg/l.

Phosphorus results cannot be accurately interpreted since the presence of arsenic interferes with this test. Unusually high soluble phosphorus results of 23 ug/l and up were due in part to the presence of arsenic which may be measured as phosphorus in the phosphate determination.

Even allowing for arsenic interference, total phosphorus concentrations at Station 11 are sufficiently high at 200-300 ug/l to indicate a waste input carried by Deer Creek. Total phosphorus values fluctuated from 200 to 1200 ug/l at Station 36 in the eastern basin, indicating a possible waste input in that area. Total phosphorus values at the other stations were in the 30-50 ug/l range in June, increasing to 66-145 ug/l in September. Stations 1 and 3 in the western basin were lower than the stations in the eastern basin were lower than the stations in the eastern basin which is consistent with their location upstream from the major phosphorus input, Deer Creek.

Total Kjeldahl concentrations were generally in the 1000 ug/l range, accompanied by 100-200 ug/l free ammonia. Stations 11 and 36 had 50% higher average total Kjeldahl values for the survey period than the other stations.

Iron concentrations were generally low at .05 to .15 mg/l, even when elevated phosphorus values were observed. The sole exception to this was

at Station 11 where concentrations were high and fluctuated widely, for example, 0.30 mg/l and 2.6 mg/l two days apart.

Moir Lake is sufficiently shallow and well mixed that during the surveys oxygen was never observed to be completely absent from the bottom waters, but on several occasions dissolved oxygen (DO) values well below saturation were detected. The lowest levels, slightly less than 4.0 mg/l, were recorded in the bottom waters at Stations 24 and 36 between August 23 and August 25.

There was no evidence of nutrient regeneration other than a slight increase in phosphorus, iron and hardness in a single bottom sample, at Station 24 on June 21. However, periods of more extensive oxygen depletion approaching 0 mg/l have occurred in the past during calm weather and were associated with nutrient regeneration from the bottom sediments (G. Owen personal communication).

Deer Creek, carrying the sewage wastes from the Town of Madoc, was confirmed by many of the results at Station 11 to be a substantial source of chemical pollution to Moira Lake. Discharge of inadequately treated municipal wastes to Deer Creek was terminated during the summer of 1972 as the new treatment lagoons installed by the Town of Madoc were being filled. Results on frequent regular samples collected from Deer Creek below Madoc by the MOE throughout the fall of 1972 and the winter of 1972-73, showed a marked improvement in all aspects of water chemistry, to levels within the objectives of the Ministry. The treated wastes which were first released from the lagoon in the spring of 1973 were sampled by the Sanitary Engineering Branch of the Ministry and also met the objec-

tives of the Ministry for chemical quality. They exerted no detectable effect on the water quality of Deer Creek.

Chlorophyll a and Water Clarity

As indicated by chlorophyll a concentrations, all three deep-water sampling stations were characterized by very large amounts of suspended algae in the illuminated zone of the lake. The mean chlorophyll a concentration in the lake over the three surveys of 26 ug/l was accompanied by a mean Secchi disc transparency of 1.1m. Three extremely high chlorophyll a concentrations between 70 and 84 ug/l were recorded and were accompanied by Secchi disc transparencies as low as 0.5m - indicating water of very poor clarity. Nutrients such as phosphorus were in abundant supply and no doubt contributed to the proliferation of algae in the lake.

On a scale of lake enrichment as indicated by chlorophyll a concentrations and water transparency, Moira Lake is extremely enriched (Figure 5). Preliminary studies on other lakes similarly affected by high nutrient loadings from municipal waste treatment facilities have indicated an improvement in water quality following either diversion of the waste effluent or nutrient removal at the treatment. A gradual improvement in Moira Lake water quality in terms of increased clarity and smaller amounts of suspended algae may be expected following the addition of phosphorus removal to the existing lagoon treatment at Madoc.

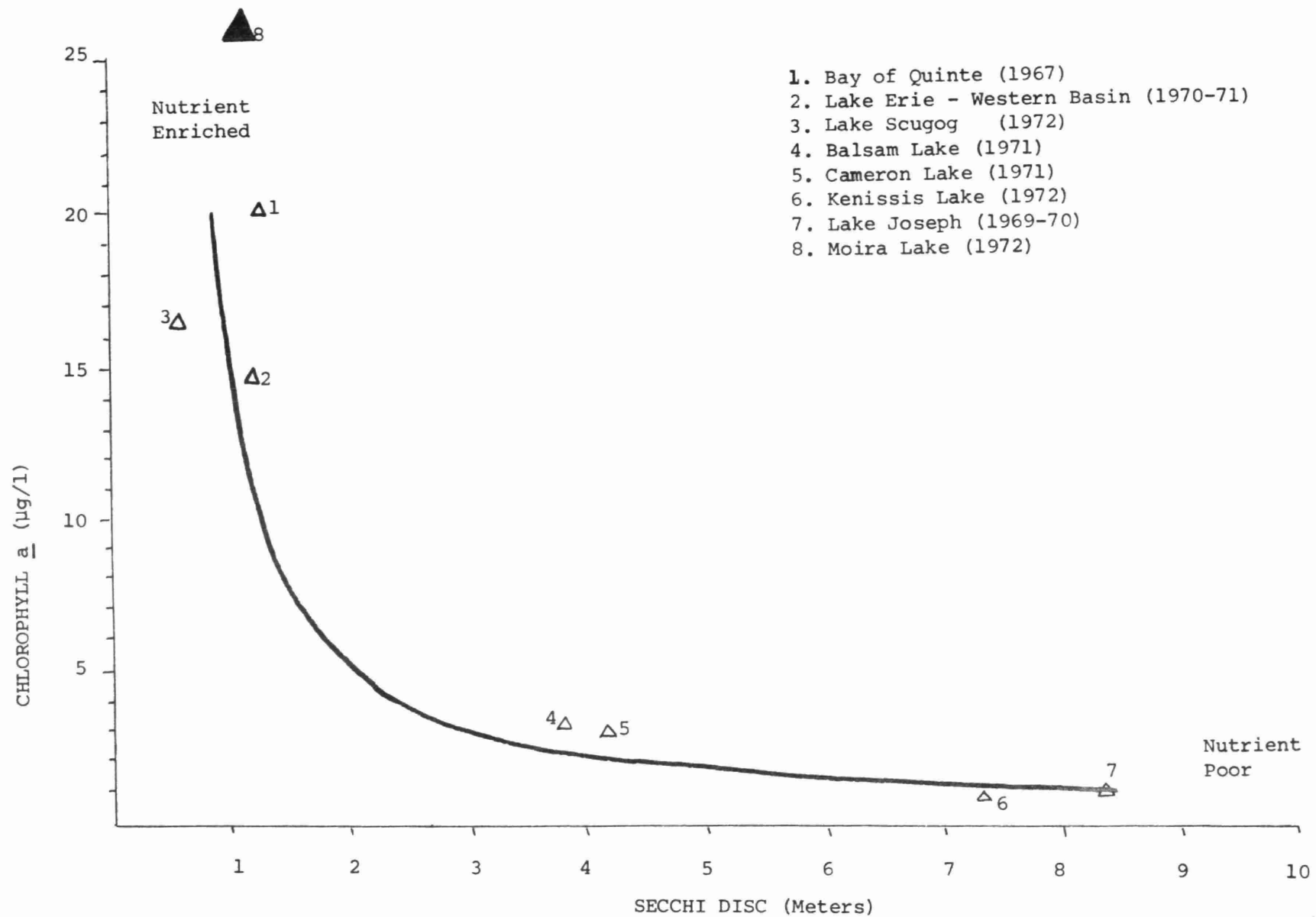


Figure : The mean of chlorophyll a and Secchi disc measurements in Moira Lake relative to a curve describing the chlorophyll a - Secchi disc relationship in many Ontario lakes. Seven other well known lakes are included for comparison with Moira Lake.

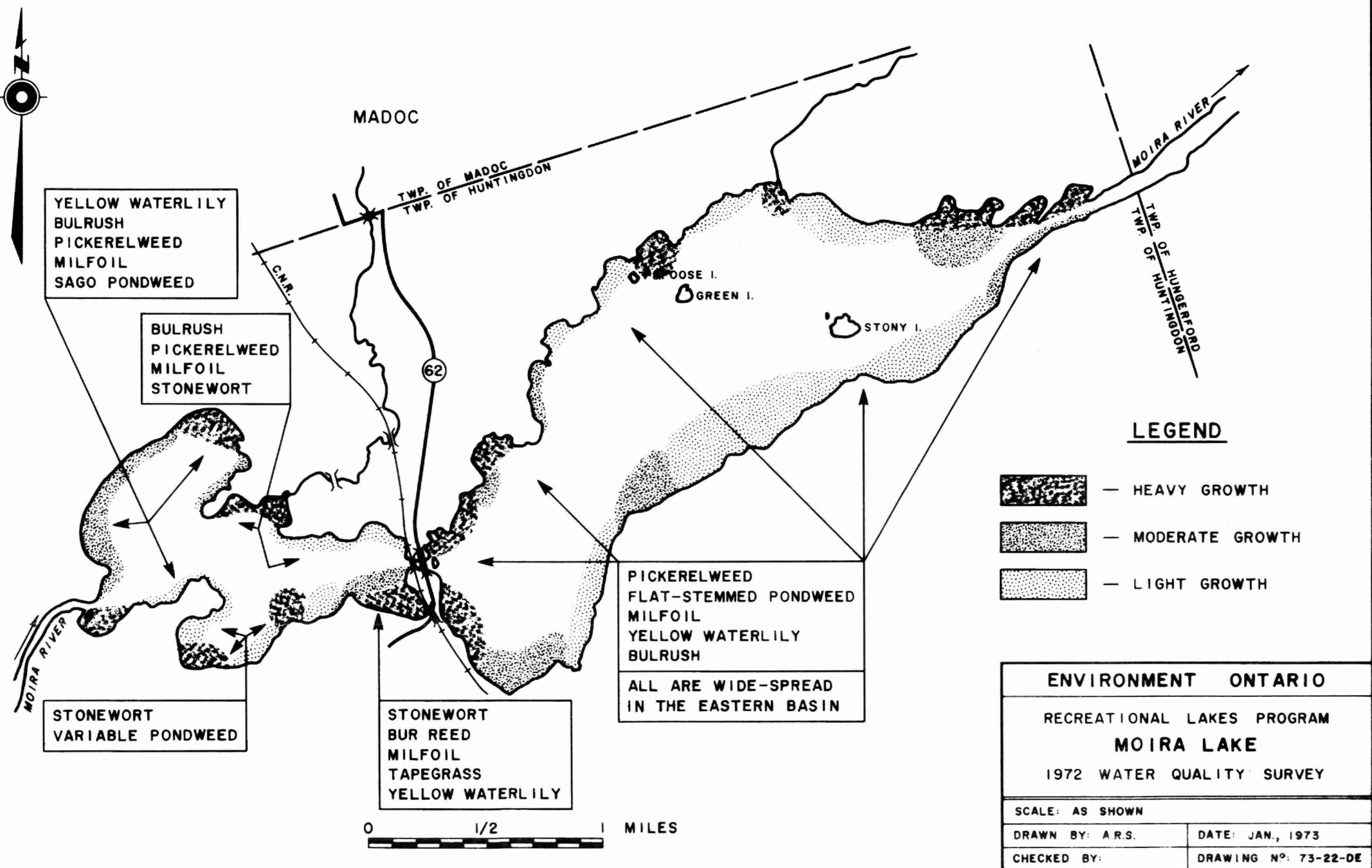
Aquatic Plants in Shoreline Areas

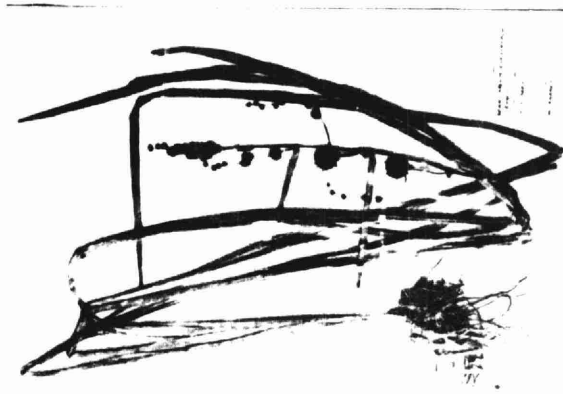
Aquatic plants representing seven genera, from which five different species were identified were found in shoreline areas of Moira Lake (Table 1). Many of the plants could only be identified to genus because they lacked the fruiting or flowering structures necessary for complete identification. Figure 6 outlines the location and extent of the plant growth and lists the plants found in each area. While this figure shows the distribution and total density of the plants, the density of dominance of any particular plant type was not determined. Figure 7 illustrates some of the common plants found in Moira Lake. It is apparent that not only did Moira Lake provide a suitable habitat for aquatic plants owing to its shallowness and fertile bottom deposits, but that the abundant nutrients in the lake supported algal and plant communities, both of which thrived to an objectionable degree. The decomposition of such excessive plant and algal growths and the resultant loss of dissolved oxygen has no doubt contributed to the intermittent fish mortalities reported in the past. Control of plant growth (see page A-10) in the lake may become a necessary lake management tool in future years if a greater variety of recreational pursuits is to be realized.

Future Considerations

Intensive water quality monitoring within the Moira River basin by both the Ministry of Health and the Ministry of the Environment over the past several years has revealed a steady improvement with arsenic concentrations now approaching the Ministry's objective. This is largely the result of extensive treatment of both surface and subsurface water at the

FIGURE 6 - MAJOR AREAS OF SHORELINE AQUATIC PLANT GROWTH





BUR REED



BULRUSH



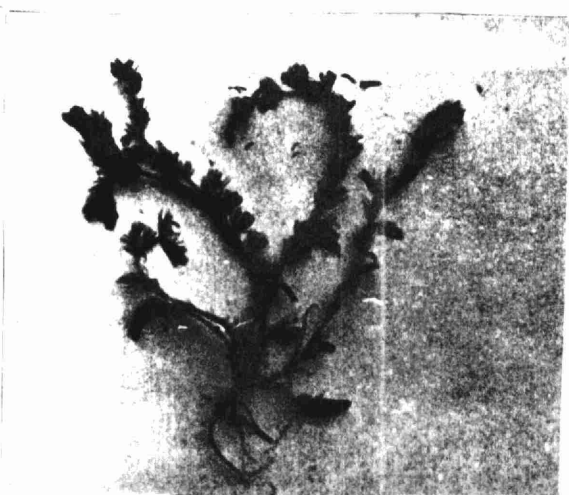
STONEWORT



PICKERELWEED



SAGO PONDWEED



MILFOIL

Figure 7: Photographs of some common aquatic plants found in Moira Lake.

vacant site of the Deloro Smelting and Refining Company. A 1973 report entitled "Abatement of Arsenic Contamination in Moira River at Deloro" by the Industrial Waste Branch of the Ministry of the Environment will outline the work completed at that date regarding the installation of arsenic treatment facilities at sources of contamination.

Of great concern to cottagers and Ministry staff is the excessively enriched and productive state of the lake. In addition to the reduction in nutrients which has been achieved by the installation of the new sewage treatment lagoons at Madoc in 1972, removal of phosphorus by chemical precipitation in the lagoons will be incorporated by the end of 1973. In continuation of the work which resulted in the report "Biological Survey of the Moira River" (OWRC 1969), an evaluation will be made of the changes in Moira Lake water quality which occur as a result of a reduction in phosphorus inputs to the lake. In this regard, considerable background data on the lake, in addition to this report, will be gathered under a cooperative program involving regional Ministry staff and the local conservation authority with respect to seasonal and lake-wide distribution of nutrients, dissolved oxygen, aquatic plants and algae.

Investigations are underway elsewhere to determine conditions for the effective use of chemical precipitants as a lake management tool to improve water clarity by flocculating suspended algae and other particulate matter in highly enriched lakes. This technique along with the harvesting of aquatic plants, may find application in Moira Lake in future.

INFORMATION OF GENERAL INTEREST TO COTTAGERS MICROBIOLOGY OF WATER

For the sake of simplicity, the microorganisms in water can be divided into two groups: the bacteria that thrive in the lake environment and make up the natural bacterial flora; and the disease causing microorganisms, called pathogens, that have acquired the capacity to infect human tissues.

The "pathogens" are generally introduced to the aquatic environment by raw or inadequately treated sewage, although a few are found naturally in the soil. The presence of these bacteria does not change the appearance of the water but pose an immediate public health hazard if the water is used for drinking or swimming. The health hazard does not necessarily mean that the water user will contract serious waterborn infections such as typhoid fever, polio or hepatitis, but he may catch less infections of gastroenteritis (sometimes called stomach flu), dysentery or diarrhea. Included in these minor afflictions are eye, ear and throat infections that swimmers encounter every year and the more insidious but seldom diagnosed, subclinical infections usually associated with several water born viruses. These viral infections leave a person not feeling well enough to enjoy holidaying although not bedridden. This type of microbial pollution can be remedied by preventing wastes from reaching the lake and water quality will return to satisfactory conditions within a relatively short time (approximately 1 year) since disease causing bacteria usually do not thrive in an aquatic environment.

The rest of the bacteria live and thrive within the lake environment. These organisms are the instruments of biodegradation. Any organic

matter in the lake will be used as food by these organisms and will give rise, in turn to subsequent increases in their numbers. Natural organic matter as well as that from sewage, kitchen wastes, oil and gasoline are readily attached by these lake bacteria. Unfortunately, biodegradation of the organic wastes by organisms uses correspondingly large amounts of the dissolved oxygen. If the organic matter content of the lake gets high enough, these bacteria will deplete the dissolved oxygen supply in the bottom waters and threaten the survival of many deep water fish species.

The standard plate count (SPC) populations given in the text supply an indication of the number of these bacteria in the lake.

RAINFALL AND BACTERIA

The "Rainfall Effect" referred to in the text, relates to a phenomena that has been documented in previous surveys of the Recreational Lakes. Heavy precipitation has been shown to flush the land area around the lake and the subsequent runoff will carry available contaminants including sewage organisms as well as natural soil bacteria with it into the water.

Total coliforms, fecal coliforms and fecal streptococci, as well as other bacteria and viruses which inhabit human waste disposal systems, can be washed into the lake. In Precambrian areas where there is inadequate soil cover and in fractured limestone areas where fissures in the rocks provide access to the lake, this phenomenon is particularly evident.

Melting snow provides the same transportation function for bacteria, especially in an agricultural area where manure spreading is carried out in the winter on top of the snow.

Previous data from sampling points situated 50 to 100 feet from shore indicate that contamination from shore generally shows up within 12 to 48 hours after a heavy rainfall.

WATER TREATMENT

Lake and river water is open to contamination by man, animals and birds (all of which can be carriers of disease); consequently, NO SURFACE WATER MAY BE CONSIDERED SAFE FOR HUMAN CONSUMPTION without prior treatment, including disinfection. Disinfection is especially critical if coliforms have been shown to be present.

Disinfection can be achieved by:

(a) Boiling

Boil the water for a minimum of five minutes to destroy the disease causing organisms.

(b) Chlorination Using a Household Bleach Containing 4 to 5.1/4% Available Chlorine

Eight drops of a household bleach solution should be mixed with one gallon of water and allowed to stand for 15 minutes before drinking.

(c) Continuous Chlorination

For continuous water disinfection, a small domestic hypochlorinator (sometime coupled with activated charcoal filters) can be obtained from a local plumber or water equipment supplier.

(d) Well Water Treatment

Well water can be disinfected using a household bleach (assuming

strength at 5% available chlorine) if the depth of water and diameter of the well are known.

CHLORINE BLEACH
per 10 ft depth of water

Diameter of Well Casing In Inches	One to Ten Coliforms	More than Ten Coliforms
4	.5 oz	1 oz.
6	1 oz.	2 oz.
8	2 oz.	4 oz.
12	4 oz.	8 oz.
16	7 oz.	14 oz.
20	11 oz.	22 oz.
24	16 oz.	31 oz.
30	25 oz.	49 oz.
36	35 oz.	70 oz.

Allow about six hours of contact time before using the water.

Another bacteriological sample should be taken after one week of use.

Water Sources (spring, lake, well, etc.) should be inspected for possible contamination routes (surface soil, runoff following rain and seepage from domestic waste disposal sites). Attempts at disinfecting the water alone without removing the source of contamination will not supply bacteriologically safe water on a continuing basis.

There are several types of low cost filters (ceramic, paper, carbon, diatomaceous earth sometimes impregnated with silver, etc.) that can be easily installed on taps or in water lines. These may be useful to remove particles if water is periodically turbid and are usually very successful. Filters, however, do not disinfect water but may reduce bacterial numbers. For safety, chlorination of filtered water is recommended.

SEPTIC TANK INSTALLATIONS

In Ontario, provincial law requires that you obtain permission in writing to install a septic tank system. Permission can be obtained from the local Medical Officer of Health or in some instances from the Regional Engineer of the Ministry of the Environment. Any other pertinent information such as sizes, types and location of septic tanks and tile fields can also be obtained from the same authority.

(i) General Guidelines

A septic tank should not be closer than:

- 50 feet to any well, lake, stream or pond.
- 5 feet to any building.
- 10 feet to any property boundary

The tile field should not be closer than:

- 100 feet to the nearest dug well.
- 50 feet to a drilled well which has a casing to 25 feet below ground.
- 25 feet to a building
- 10 feet to a property boundary.
- 50 feet to any lake, stream or pond.

The ideal location for a tile field is in a well drained, sandy loam soil remote from any wells or other drinking water sources. For the tile field to work satisfactorily, there should be at least 3 feet of soil between the bottom of the weeping tile trenches and the top of the ground water table or bedrock.

DYE TESTING OF SEPTIC TANK SYSTEMS

There is considerable interest among cottage owners to dye test their sewage systems, however, several problems are associated with dye testing. Dye would not be visible to the eye from a system that has a fairly direct

connection to the lake. Thus, if a cottager dye-tested his system and no dye was visible in the lake, he would assume that his system is satisfactory, which might not be the case. A low concentration of dye is not visible and therefore expensive equipment such as a fluorometer is required. Only qualified people with adequate equipment are capable of assessing a sewage system by using dye. In any case, it is likely that some of the water from a septic tank will eventually reach the lake. The important question is whether all contaminants including nutrients have been removed before it reaches the lake. To answer this question special knowledge of the system, soil depth and composition, underground geology of the region and the shape and flow of the shifting water table are required. Therefore, we recommend that this type of study should be performed only by qualified professionals.

BOATING REGULATION

In order to help protect the lakes and rivers of Ontario from pollution it is required by law that sewage (including garbage) from all pleasure craft, including houseboats must be retained in equipment of a type approved by the Ministry of the Environment. Equipment which will be approved by the Ministry of the Environment includes (1) retention devices with or without circulation which retain all toilet wastes for disposal ashore, and (2) incinerating devices which reduce all sewage to ash.

To be approved, equipment shall:

1. be non-portable,
2. be constructed of structurally sound material,
3. have adequate capacity for expected use
4. be properly installed,

5. in the case of storage devices, be equipped with the necessary pipes and fittings conveniently located for pump-out by shore-based facilities (although not specified, a pump-out deck fitting with 1.1/2 inch National Pipe Thread is commonly used).

An Ontario regulation requires that marinas and yacht clubs provide or arrange pump-out service for the customers and members who have toilet-equipped boats. In addition, all marinas and yacht clubs must provide litter containers that can be conveniently used by occupants of pleasure boats.

The following "Tips" may be of assistance to you in regards to boating:

1. Motors should be in good mechanical condition and properly tuned.
2. When a tank for outboard motor testing is used, the contents should not be emptied into the water.
3. Fuel hoses must be in good condition and all connections tight.
4. If the bilge is cleaned prior to the boating season, the waste material must not be dumped into the water.
5. Fuel tanks must not be overfilled and space must be left for expansion if the fuel warms up.
6. Vent pipes should not be obstructed and fuel needs to be dispensed at a correct rate to prevent "blow-back".
7. Empty oil cans must be deposited in a leak-proof receptacle.

ICE-ORIENTED RECREATIONAL ACTIVITIES

The Ministry of the Environment is presently preparing regulations to control pollution from ice-oriented recreational activities. In past years, there has been indiscriminate dumping of garbage and sewage on the ice. The bottoms of fish huts have been left on the ice and become a navigational hazard to boaters in the spring. Broken glass has been left on the ice only to become

injurious to swimmers. With the anticipated introduction of the regulations, many of these abuses will become illegal.

EUTROPHICATION OR EXCESSIVE FERTILIZATION AND LAKE PROCESSES

The changes in water quality brought about by excessive inputs of nutrients to lakes are usually evidenced by excessive growths of algae and aquatic plants.

Aquatic plants and algae are important in maintaining a balanced aquatic environment. They provide food and a suitable environment for the growth of aquatic invertebrate organisms which serve as food for fish. Shade from large aquatic plants helps to keep the lower water cool which is essential to certain species of fish and also provide protection for young game and forage fish. Numerous aquatic plants are utilized for food and/or protection by many species of waterfowl. However, too much growth creates an imbalance in the natural plant and animal community particularly with respect to oxygen conditions, and some desirable forms of life such as sport fish are eliminated and unsightly algae scums can form. The lake will not be "dead" but rather abound with life which unfortunately is not considered aesthetically pleasing. This change to poor water quality becomes apparent after a period of years in which extra nutrients are added to the lake and a return to the natural state may also take a number of years after the nutrient inputs are stopped. Changes in water quality with depth are a very important characteristic of a lake. Water temperatures are uniform throughout the lake in the early spring and winds generally keep the entire volume well mixed. Shallow lakes may remain well mixed all summer so that water quality will be the same throughout. On the other hand, in deep lakes, the surface waters

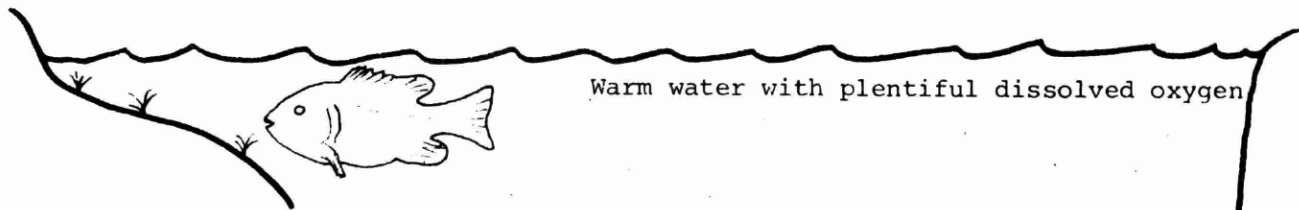
warm up during late spring and early summer and float on the cooler more dense water below. The difference in density offers a resistance to mixing by wind action and many lakes do not become fully mixed again until the surface waters cool down in the fall. The bottom water receives no oxygen from the atmosphere during this unmixed period and the dissolved oxygen supply may be all used up by bacteria as they decompose organic matter. Cold water fish, such as trout, will have to move to the warm surface waters to get oxygen and because of the high water temperatures they will not thrive, so that the species will probably die out (see Figure next page).

Low oxygen conditions in the bottom waters are not necessarily an indication of pollution but excessive aquatic plant and algae growth and subsequent decomposition can aggravate the condition and in some cases can result in zero oxygen levels in lakes which had previously held some oxygen in the bottom waters all summer. Although plant nutrients normally accumulate in the bottom waters of lakes, they do so to a much greater extent if there is no oxygen present. These nutrients become available for algae in the surface waters when the lake mixes in the fall and dense algae growths can result. Consequently, lakes which have no oxygen in the bottom water during the summer are more prone to having algae problems and are more vulnerable to nutrient inputs than lakes which retain some oxygen.

CONTROL OF AQUATIC PLANTS AND ALGAE

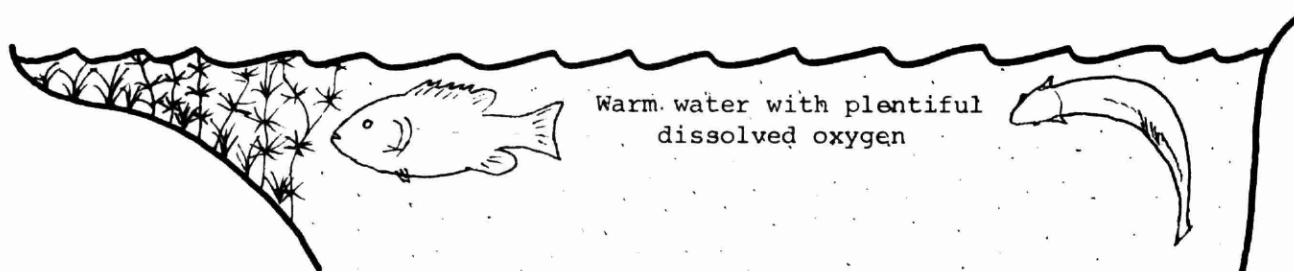
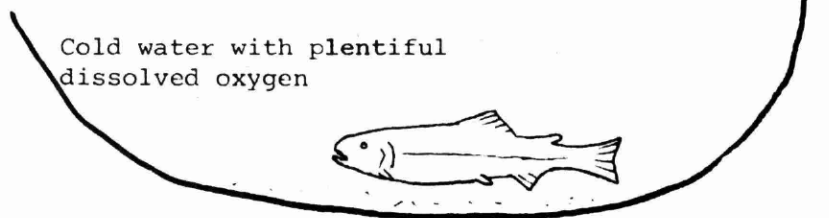
Usually aquatic weed growths are heaviest in shallow shoreline areas where adequate light and nutrient conditions prevail.

Extensive aquatic plant and algal growths sometimes interfere with



Surface water and shallows are normally inhabited by warm-water fish such as bass, pike and sunfish.

Bottom waters containing plentiful dissolved oxygen are normally inhabited by cold water species such as lake trout and whitefish.



When excessive nutrients entering a lake result in heavy growths of algae and weeds, the bottom waters are often depleted of dissolved oxygen when these plants decompose. Cold-water species of fish are forced to enter the warm surface waters to obtain oxygen where the high temperatures may be fatal.

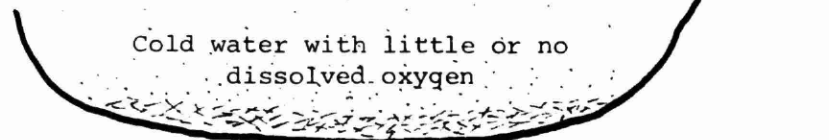


FIGURE A-1: DECOMPOSITION OF PLANT MATTER AT THE LAKE BOTTOM CAN LEAD TO DEATH OF DEEP-WATER FISH SPECIES.

boating and swimming and ultimately diminish shoreline property values.

Control of aquatic plants may be achieved by either chemical or mechanical means. Chemical methods of control are currently the most practical, considering the ease with which they are applied. However, the herbicides and algicides currently available generally provide control for only a single season. It is important to ensure that an algicide or herbicide which kills the plants causing the nuisance, does not affect fish or other aquatic life and should be reasonable in cost. At the present time, there is no one chemical which will adequately control all species of algae and other aquatic plants. Chemical control in the province is regulated by the Ministry of the Environment and a permit must be granted prior to any operation. Simple raking and chain dragging operations to control submergent species have been successfully employed in a number of situations; however, the plants soon re-establish themselves. Removal of weeds by underwater mowing techniques is certainly the most attractive method of control and is currently being evaluated in Chemung Lake near Peterborough. Guidelines and summaries of control methods, and applications for permits are available from the Biology Section, Water Quality Branch, Ministry of the Environment, Box 213, Rexdale, Ontario.

PHOSPHORUS AND DETERGENTS

Scientists have recognized that phosphorus is the key nutrient in stimulating algal and plant growth in lakes and streams.

In the past years, approximately 50% of the phosphorus contributed by municipal sewage was added by detergents. Federal regulations reduced

the phosphate content as P_2O_5 in laundry detergents from approximately 50% to 20% on August 1, 1970 and to 5% on January 1, 1973.

It should be recognized that automatic dishwashing compounds were not subject to the recently approved government regulations and that surprisingly high numbers of automatic dishwashers are present in resort areas (a questionnaire indicated that about 30% of the cottages in the Muskoka Lakes have automatic dishwashers). Cottagers utilizing such conveniences may be contributing significant amounts of phosphorus to recreational lakes. Indeed, in most of Ontario's vacation land, the source of domestic water is soft enough to allow the exclusive use of liquid dishwashing compounds, soap and soap-flakes.

ONTARIO'S PHOSPHORUS REMOVAL PROGRAM

By 1975, the Government of Ontario expects to have controls in operation at more than 200 municipal wastewater treatment plants across the province serving some 4.7 million persons. This represents about 90% of the population serviced with sewers. The program is in response to the International Joint Commission recommendations as embodied in the Great Lakes Water Quality Agreement and studies carried out by the Ministry of the Environment on inland recreational waters which showed phosphorus to be a major factor influencing eutrophication. The program makes provision for nutrient control in the Upper and Lower Great Lakes, the Ottawa River system and in prime recreational waters where the need is demonstrated or where emphasis is placed upon prevention of localized eutrophication.

Phosphorus removal facilities must be operational at wastewater treatment plants by December 31, 1973, in the most critically affected areas

of the province, including all of the plants in the Lake Erie drainage basin and the inland recreational areas. The operational date for plants discharging to waters deemed to be in less critical condition which includes plants larger than one million gallons per day (1 mgd) discharging to Lake Ontario and to the Ottawa River system, is December 31, 1975. The 1973 phase of the program will involve 156 plants of which 85 are in the Lake Erie basin and another 30 in the Lake Huron drainage basin. The capacities of these plants range from 0.04 to 24.0 mgd, serving an estimated population of 1,600,000 persons. The 1975 phase will bring into operation another 57 plants ranging in size from 0.3 to 180 mgd serving an additional 3,100,000 persons. Treatment facilities utilizing the Lower Great Lakes must meet effluent guidelines of less than 1.0 milligrams per litre of total phosphorus in their final effluent. Facilities utilizing the Upper Great Lakes, the Ottawa River Basin and certain areas of Georgian Bay where needs have been demonstrated must remove at least 80% of the phosphorus reaching their sewage treatment plants.

CONTROL OF BITING INSECTS

Mosquitoes and blackflies often interfere with the enjoyment of recreational facilities at the lake-side vacation property. Pesticidal spraying or fogging in the vicinity of cottages produces extremely temporary benefits and usually do not justify the hazard involved in contaminating the nearby water. Eradication of biting fly populations is not possible under any circumstances and significant control is rarely achieved in the absence of large-scale abatement programmes involving substantial funds and trained personnel. Limited use of approved

larvicides in small areas of swamp or in rain pools close to residences on private property may be undertaken by individual landowners, but permits are necessary wherever treated waters may contaminate adjacent streams or lakes. The use of repellents and light traps is encouraged as are attempts to reduce mosquito larval habitat by improving land drainage. Applications for permits to apply insecticides as well as technical advice can be obtained from the Biology Section, Water Quality Branch of the Ministry of the Environment, Box 213, Rexdale, Ontario.